# Supplementary Material for paper: *Protein futures for Western Europe: potential land use and climate impacts in 2050* published in Regional Environmental Change

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## S1. Summary of modelled scenarios

**Table S1**. Overview of the scenarios modelled in this study

| | Business-as-usual (BAU) | Yields and Waste | Intensive Livestock | Dairy and Poultry | Dairy and Aquaculture | Artificial Meat and Dairy | Ecological Leftovers | Plant Based Eating |
|---|---|---|---|---|---|---|---|---|
| Yield levels in plant production | Current yield trends (Bajželj et al., 2014) | Yield gap closed (Bajželj et al., 2014) | | | | | | |
| Waste | Reduced by 50% from current levels (current level from FAO, 2011) | | | | | | | |
| Amount of animal products consumed | For Projected Diet as projected by FAO[1] / For Healthy Diet as defined in Bajželj et al. (2014)[2] | | | | | | As much as can be produced on 'ecological leftovers'' evenly distributed over the population (red meat capped at healthy levels) | None. Livestock products are replaced by pulses and cereals on caloric basis. |
| Type of animal product | Mix of beef, pork, poultry, egg, dairy and seafood corresponding to current consumption patterns[3]. | | | Milk and beef meat from dairy cows and their off-spring. Remaining animal product | Milk and beef meat from dairy cows and their off-spring. | Artificial Meat and Dairy and milk, insects and other novel protein sources (e.g. algae) | Milk and beef meat from dairy cows and their off-spring. Pig meat. | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | calories supplied by chicken. | Remaining animal product calories supplied by aquaculture products. | | | |
| Type of production system | Slight efficiency increase from today's system as projected by (Bajželj et al., 2014) | Slight efficiency increase from today's system as projected by (Bajželj et al., 2014) | Intensive systems corresponding to best practice systems in the developed world[4] | Intensive systems corresponding to best practice systems in the developed world[4]<br>Milk yield 11,000 kg per cow per year. | Intensive systems corresponding to best practice systems in the developed world[4]<br>Milk yield 11,000 kg per cow per year. | Highly industrialized, e.g. cyanobacteria cultivated on land in a concrete open pond.<br>Uses no agricultural land. | Dairy herds raised on pasture and fibre-rich by-products.<br>Milk yield 6,400 kg per cow per year.<br>Pigs raised on food waste, oil cake and cereals. | All on cropland, intensive (yield gaps closed). |
| Use of by-products | As projected by (Bajželj et al., 2014) | As projected by (Bajželj et al., 2014) | Fibre rich by-products used as ruminant feed, oil cake used for dairy and monogastrics. No use of food waste as feed due to assumed continuation of current EU animal by-products regulations. | Fibre rich by-products used as ruminant feed, oil cake used for dairy and poultry. No use of food waste as feed due to assumed continuation of current EU animal by-products regulations. | Fibre rich by-products and oil cake used. | Not used for food. | Fibre rich by-products and oil cake used as ruminant feed, oil cake used for pig production in combination of food waste and some cereals. | Not used for food. |

1 Se Supplementary table 2 in Bajželj et al. (2014)

2 Se Supplementary table 3 in Bajželj et al. (2014)

3 According to FAOSTAT Food Balance Sheet for Western, Northern and Southern Europe.

4 Modelled as current best practice systems in Sweden; Bertilsson et al., 2014; Supplementary Material S4.

## S2. Foods in diets

Table S2 shows the daily amounts of animal foods consumed in the Projected Diets (PD) and Healthy Diets (HD) for the different scenarios as well as amounts of additional pulses, cereals and vegetable oil to substitute for animal protein and fat in the Dairy and Aquaculture, Plant Based Eating and Ecological Leftovers scenarios, in comparison with consumption in 2009 (Bajželj et al., 2014). Table S3 shows amount of plant-based foods which are the same for all scenarios.

**Table S2**. Daily amounts of animal foods consumed (after waste) and additional pulses, cereals and vegetable oil to substitute for animal protein and fat in the Plant Based Eating and Ecological Leftovers scenarios as well as total protein content for the complete Projected Diet (PD) and Healthy Diet (HD) for the different scenarios. Meat in carcass weight, fish in edible weight. Foods consumed 2009 from Bajželj et al. (2014).

| | Consumed 2009 | Intensive Livestock | | Dairy and Poultry | | Dairy and Aqua-culture | | Artificial Meat and Dairy | | Plant Based Eating | | Ecological Leftover | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal foods: | | PD | HD | PD | HD | PD | HD | PD | HD | PD | HD | PD | HD |
| Beef dairy, g | 45[1] | 14 | 11 | 14 | 11 | 14 | 11 | | | | | 21 | 16 |
| Beef suckler, g | | 48 | 7 | | | | | 340[3] | 163[3] | | | 52 | |
| Pig meat, g | 93 | 99 | 15 | | | | | | | | | 36 | 16 |
| Poultry, g | 51 | 57 | 57 | 330 | 154 | | | | | | | | |
| Egg, g | 28 | 34 | 34 | | | | | | | | | | |
| Dairy, g | 521 | 519 | 400 | 519 | 400 | 519 | 400 | 519[3] | 400[3] | | | 519 | 400 |
| Capt. seafood, g | 33[2] | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Farmed seafood, g | | 22 | 22 | | | 253 | 112 | | | | | | |
| Veg oil, g | | | | | | 1 | 2 | | | | | | |
| Pulses, g | | | | | | | | | | 76 | 47 | 25 | 14 |
| Cereals, g | | | | | | | | | | 196 | 121 | 65 | 37 |
| Protein in total, g | | 94 | 86 | 108 | 90 | 106 | 88 | 104 | 88 | 70 | 72 | 81 | 75 |

1 Meat from both dairy and suckler production systems
2 Seafood from both capture fisheries and aquaculture
3 Artificial meat and milk

**Table S3**. Daily amounts of plant based foods consumed (after waste) and total energy content (including animal foods) in the Projected Diet (PD) and Healthy Diet (HD). Same amounts in all scenarios. Foods consumed 2009 from Bajželj et al. (2014).

| | Consumed 2009 | For all scenarios | |
|---|---|---|---|
| Plant-based foods: | | PD | HD |
| Vegetables, g | 225 | 174 | 527 |
| Fruit, g | 226 | 223 | 295 |
| Sugar, g | 92 | 95 | 43 |
| Veg oils, g | 58 | 60 | 41 |
| Wheat, g | 199 | 198 | 279 |
| Rice, g | 12 | 12 | 17 |
| Maize, g | 24 | 23 | 23 |

| | | | |
|---|---|---|---|
| Other grains, g | 13 | 26 | 36 |
| Roots, g | 145 | 120 | 169 |
| Pulses, g | 8 | 8 | 8 |
| Other crops, g | 72 | 20 | 25 |
| Total energy, kcal | 2727 | 2738 | 2500 |

# S3. Calculations of land use

### S3.1 Business-As-Usual and Yields and Waste

The land use results for the BAU and Yields and Waste scenarios were taken from Bajželj et al. (2014). The CT1, YG2 and YG3 scenarios in the Bajželj et al. (2014) were adjusted to exclude trade, fallow land and cultivation of crops for non-food uses (biofuel, cotton etc.) hence showing only the land needed to produce the food for the projected population in Western Europe.

### S3.2 Intensive Livestock

A detailed description of how land use was calculated is given for the Dairy and Poultry scenario in section S3.3. Steps [1]-[22] apply to the Intensive Livestock scenario as well. The amount of projected beef meat not supplied by the dairy system is assumed to be produced in a suckler cow/calf system described in section S4.1. Production of pig and poultry meat, egg and farmed seafood (deducted by the amount of seafood from wild fisheries) is described in section S4.1. From the total amounts of meat, fish and egg needed per year, the total amount of animals needed to be reared was calculated and from this the yearly amounts of feed needed. By using the yields for different feed crops for different regions the amount of land needed for feed production was calculated (see section S3.3 for more details).

### S3.3 Dairy and Poultry

Figure S1 illustrates the steps in calculating the land use for the Dairy and Poultry scenario. The steps are explained and data sources are given here:

[1] Plant based foods; vegetables, fruits, sugar, vegetable oil, wheat, rice, maize, other grains, roots, pulses and other crops, in the per capita diet given in energy units (kcal/day). The diet is based on current diets from FAO 2009 statistics; (FAO, 2015b) and projected changes according to FAO (Alexandratos & Bruinsma, 2012). For complete diets in kcal/day see Bajželj et al. (2014) Supplementary Table 2 and for diets in g/day consumed see Table S2 and S3 in this document.

[2] The energy content of individual food items is used to translate the food in the diet in energy units (kcal/day) to mass of food consumed per day (kg/day). Energy content was calculated based on data in FAO Food Balance Sheets for this region (FAO, 2015b).

[3] Amount of different plant-based foods in the per capita diet in kg/day. Calculated with [2].

[4] Wastes and losses in agricultural production, postharvest handling and storage, processing and packaging, distribution and retail and consumption. Weight percentages according to Annex 4 in FAO (2011).

[5] Per capita needed supply of different plant-based foods (kg/day) after accounting for wastes and losses, calculated with [4].

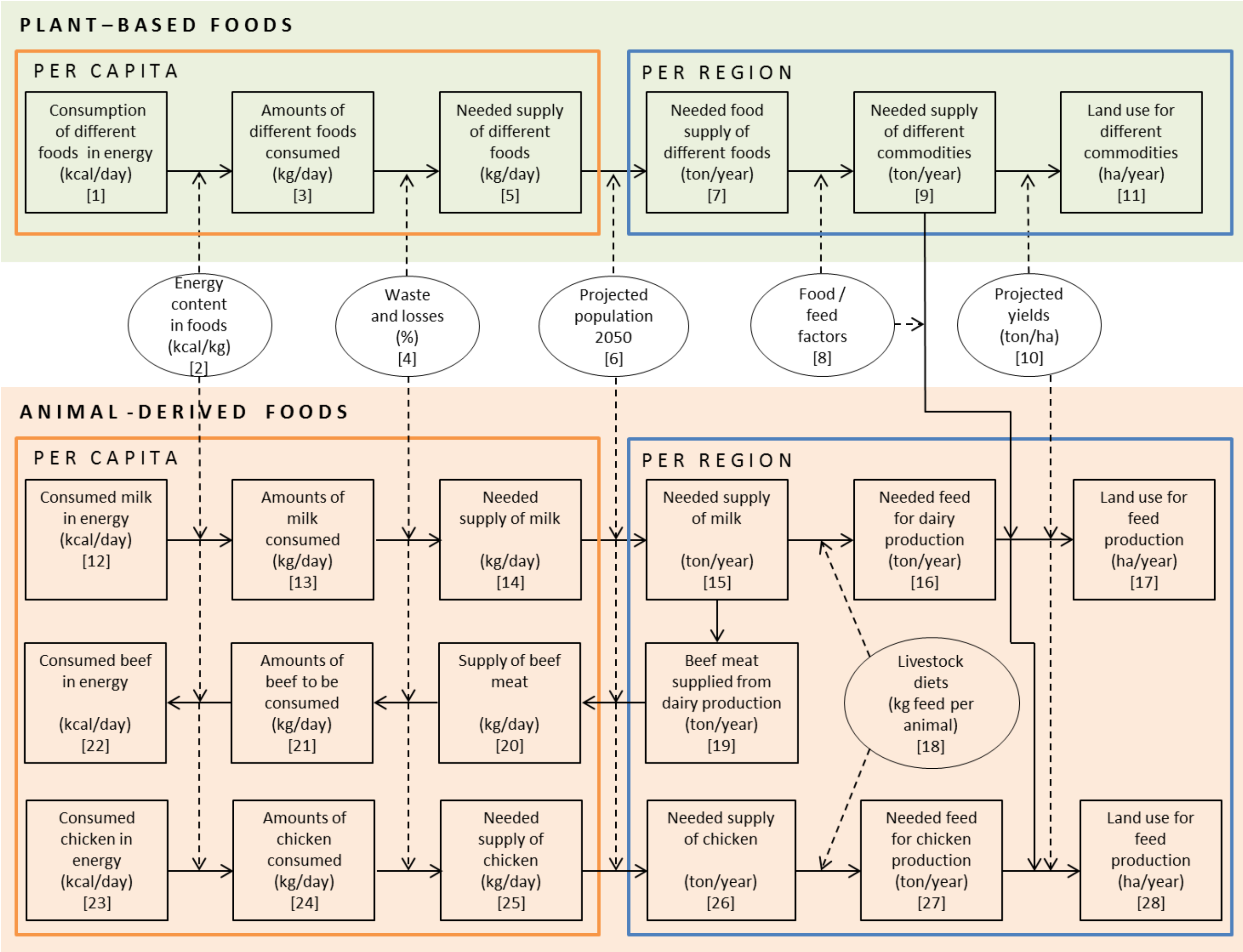


*Figure S1. Illustration of the steps in calculating the land use for the Dairy and Poultry scenario.*

[6] Populations in 2050 as projected by UN (2012).

[7] Needed plant-based food supplies for the whole region in ton/year. Calculated by multiplying the per capita food supplies for different foods in [5] with [6] and 365.

[8] Part of agricultural commodity that is used for food and feed respectively e.g. for wheat 78% is used for food and 22% as feed. Data from Annex 3 FAO (2011). It is assumed that all that is not used for food is used for feed (waste of feed in livestock production is accounted for, but assumed to be cut by 50% as all other waste).

[9] Calculated amounts of agricultural commodities needed to supply the food items in [7]. Calculated with [8].

[10] Projected yields for different commodities assuming that yield gaps are closed. Data from Supplementary Table 8 in Bajželj et al. (2014).

[11] Land use for different commodities, calculated by dividing [9] by [10].

[12] Per capita milk consumed in kcal/day, see Bajželj et al. (2014) Supplementary Table 2.

[13] Per capita milk consumed in kg/day, calculated with [2].

[14] Per capita needed supply of milk (kg/day) after accounting for wastes and losses, calculated with [4].
[15] Needed milk for the whole region in ton/year. Calculated by multiplying the per capita milk [14] with [6] and 365.
[16] The yearly amount of feed needed in dairy production to supply the milk in [15].
[17] Land use for feed for dairy production, calculated by dividing [16] by [10]. By-products supplied from the production of plant-based foods are also used as feed and decreases the land needed for feed production.
[18] Livestock diets, see section S4 for more information on animal production.
[19] The yearly amount of beef meat (ton carcass weight) supplied from the dairy cows and their off-spring.
[20] Yearly supply of beef meat per capita from dairy production, calculated by dividing [19] by [6].
[21] Yearly per capita amount of beef meat available for consumption after losses [4] in kg/day.
[22] Yearly per capita amount of beef meat available for consumption after losses [4] in kcal/day, calculated from [21] with [2].
[23] Per capita amount of poultry in kcal/day. This amount is calculated as total kcal in animal derived foods (red meat, poultry, egg, milk and fish) minus the amount of kcal supplied through milk, wild seafood and beef meat from the dairy production [22]
[24] Amount of poultry in the per capita diet in kg carcass weight/day. Calculated with [2].
[25] Per capita needed supply of poultry (kg/day) after accounting for wastes and losses, calculated with [4].
[26] Needed poultry for the whole region in ton/year. Calculated by multiplying the per capita poultry needed [25] with [6] and 365.
[27] The yearly amount of feed needed in poultry production.
[28] Land use for feed for poultry production, calculated by dividing [27] by [10]. By-products supplied from the production of plant-based foods are also used as feed and decreases the land use for feed.

### S3.4 Dairy and Aquaculture

The land use for the Dairy and Aquaculture scenario is calculated as for the Dairy and Poultry scenario described in section S3.3 with the following exception starting from step [23]: Instead of poultry, seafood is produced out of which 20% is from filter feeders and the rest from the cultivation of Tilapia (see section S4.1 for details). However, since seafood has considerably lower energy content per kg than meat the same amount in kg of seafood as chicken in the Dairy and Poultry scenario is included in the diet but not more, in order not to supply very large quantities of seafood and hence protein. In order to supply the same amount of energy in the diet some vegetable oil is added to the diet.

### S2.5 Artificial Meat

The land use for the Artificial Meat and Dairy scenario is calculated as for the Dairy and Poultry scenario described in section S3.3 up until and including step [11]. All food calories from meat, dairy, egg and farmed seafood are in this scenario supplied by artificial meat and dairy. It is assumed that no agricultural land is needed in the production of the artificial meat and dairy feedstock.

### S2.6 Plant Based eating

The land use for the Plant Based Eating scenario is calculated as for the Dairy and Poultry scenario described in section S3.3 up until and including step [11]. All food calories from meat, dairy, egg and farmed seafood are in this scenario supplied by pulses, cereals and vegetable oil. Land use for these is then calculated as for the other plant-based foods.

### S2.7 Ecological Leftovers

Figure S2 illustrates the steps in calculating the land use for the Ecological Leftovers scenario. Steps [1] – [22] are the same as for the Dairy and Poultry scenario described in section S3.3 with the exception that dairy production is based on 'ecological leftover' (see section S4.2 and S6) and some winter feed cultivated on cropland [17]. Steps [23] – [34] are explained below the figure.

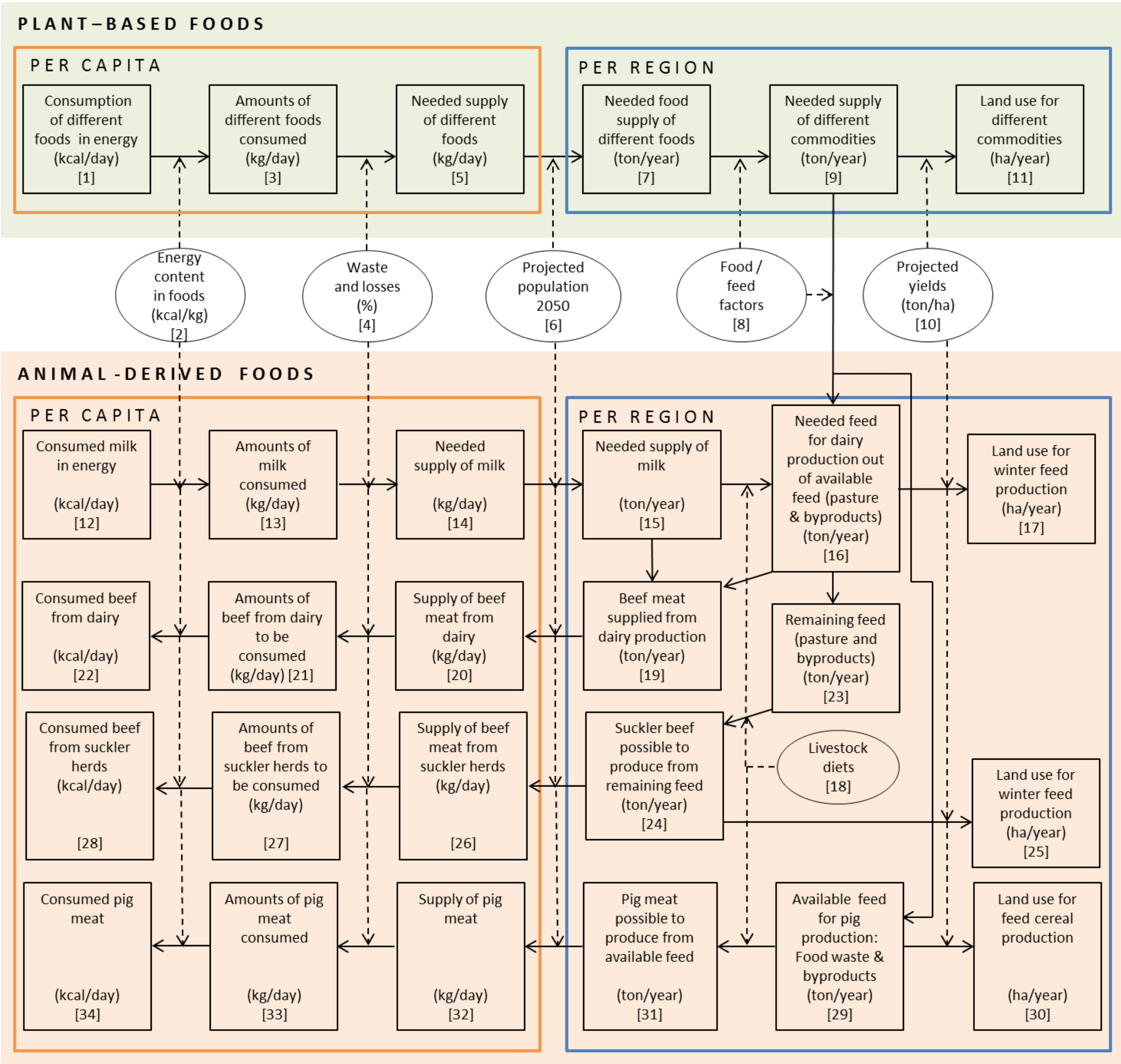


*Figure S2. Illustration of the steps in calculating the land use for the Ecological Leftovers scenario.*

[23] This is the feed from 'ecological leftovers' i.e. grazed biomass and byproducts remaining after dairy production and that are hence available for beef production using sucklar herds

[24] Beef meat from suckler herds that can be produced from the ecological leftovers in the region (ton carcass weight/year).

[26] Yearly supply of beef meat per capita from suckler herds, calculated by dividing [24] by [6].

[27] Yearly per capita amount of beef meat from suckler herds available for consumption after losses [4] in kg/day.

[28] Yearly per capita amount of beef meat from suckler herds available for consumption after losses [4] in kcal/day, calculated from [27] with [2].

[29] Ecological Leftovers; food waste and byproducts from the production of plant based foods available for pig production.

[30] Land use needed to produce cereals to complement pig diets. Calculated using [10].
[31] Pig meat that can be produced from the ecological leftovers in the region (ton carcass weight/year)
[32] Per capita supply of pig meat (kg/day), calculated from [31] divided by [6]
[33] Per capita consumption of pig meat after losses (kg/day)
[34] Per capita consumption of pig meat after losses (kcal/day)

## S4. Animal production systems

### S4.1 Intensive livestock production systems

In the Intensive Livestock, Dairy and Poultry and Dairy and Aquaculture scenarios, terrestrial livestock production were assumed to be intensified to a level that they resemble highly intensive systems currently used in industrialized countries, but without the use of hormone implants or use of antibiotics or other similar substances for growth promoting reasons. Current actual or modelled best practice systems in Sweden were used to represent these systems based on Cederberg et al. (2009), Bertilsson et al. (2014) and Spörndly (2003). Production parameters such as fertility and mortality rates, losses of milk in stables etc. were assumed to be improved by 50% from current levels.

For aquaculture production, 80% of production was assumed to be low trophic-level finfish produced in high yielding closed recirculating systems (calculations are based on Nile tilapia) (Little et al., 2008). 20% is supplied by mussels, oysters and other filter feeding, extractive bivalve species which do not require feed inputs.

Production parameters for monogastric animal production is summarized in Table S4.

**Table S4.** Production parameters for monogastric livestock production in the Intensive Livestock, Dairy and Poultry and Dairy and Aquaculture scenarios. Data for terrestrial livestock are based Cederberg et al. (2009) and Bertilsson et al. (2014) unless otherwise stated. For aquaculture production (Tilapia) data is estimated based on Pelletier and Tyedmers (2010).

| | Egg | Poultry | Pig | Aquaculture (Tilapia) |
|---|---|---|---|---|
| Feed conversion ratio | 2[1]<br>20 kg egg per hen | 1.8[2] | 3[2] | 1.7[2] |
| Feed composition | 70% cereals<br>10% oil cake[3]<br>20% f.f. bean/seed[4] | 70% cereals<br>0-1% fishmeal<br>10-14% oil cake[3]<br>14-20% f.f. bean/seed[4] | 90% cereals<br>3% oil cake[3]<br>7% f.f. bean/seed[4] | 70% cereals<br>11-16% fishmeal<br>0-7% oil cake[3]<br>3-13% f.f. bean/seed[4] |
| Carcass weight of live weight | Na | 70% | 75% | 35%[5] |
| Live weight, kg | NA | 1.9 | 115 | 0.30 |
| Human edible offal, % of live weight | NA | 3 | 3 | 0 |
| Mortality rate, % | Incl. in egg yield | 1.8 | 0.8 | 2.5 |
| Rejected at slaughter, % | NA | 0.7 | 0.15 | NA |

1 kg feed per kg egg
2 kg feed per kg live weight (including feed for parent animals)
3 By-product from vegetable oil production
4 Full fat beans and seed.
4 Edible bone-free weight.

Table S5 show data used for ruminant production in the Intensive Livestock, Dairy and Poultry and Dairy and Aquaculture scenarios. Feed rations differ between Projected Diets (PD) and Healthy Diets (HD) due to to varying amounts of by-products available from the production of the plant-based food products (Table S3). Fiber-rich by-products (FRB) are assumed to replace both cereals and forage (1 kg of FRB replace 0.5 kg cereals and 0.5 kg forage). However to ensure sufficient fibre content in the rations, the percentage of forage of the total dry matter intake was set to a minimum of 30%. Table S6 shows milk yield and other production parameters for ruminant production in the Intensive Livestock, Dairy and Poultry and Dairy and Aquaculture scenarios.

**Table S5.** Feed, slaughter age and weight for ruminant production in the Intensive Livestock, Dairy and Poultry and Dairy and Aquaculture scenarios. Data for Projected Diet / data for Healthy Diets. Variation between Projected and Healthy diets due to varying amounts of by-products. Data from Cederberg et al. (2009), Bertilsson et al. (2014) and Spörndly (2003).

| **DAIRY PRODUCTION** For the dairy cow feed consumption per year, for heifers and bulls consumption per lifetime. | | | |
|---|---|---|---|
| | Dairy cow | Heifer, dairy breed | Bull, dairy breed |
| Forage, kg d.m. | 4000 / 3600 | 4200 / 2600 | 1800 / 1100 |
| Cereals, kg | 2300 / 1900 | 400 / 400 | 1400 / 700 |
| Legumes, kg | 800 / 800 | 0 / 0 | 0 / 0 |
| Oil cake, kg | 400 / 400 | 0 / 0 | 200 / 200 |
| Fiberrich by-products, kg | 0 / 800 | 0 / 1600 | 0 / 1400 |
| Slaughter age, month | 79 | 24 | 18 |
| Slaughter weight, kg | 280 | 270 | 325 |
| **SUCKLER PRODUCTION** For the suckler cow feed consumption per year, for heifers and steers consumption per lifetime. | | | |
| | Suckler cow | Heifer, beef cattle | Bull, beef cattle |
| Forage, kg d.m. | 3000 / 2300 | 880 / 900 | 680 / 700 |
| Cereals, kg | 0 | 460 / 480 | 460 / 480 |
| Legumes, kg | 0 | 380 / 0 | 380 / 0 |
| Oil cake, kg | 0 | 360 / 740 | 360 / 740 |
| Fiberrich by-products, kg | 320 / 1000 | 640 / 600 | 640 / 600 |
| Slaughter age, month | 144 | 24 | 15 |
| Slaughter weight, kg | 340 | 280 | 300 |

**Table S6**. Production parameters for cattle production in the Intensive Livestock, Dairy and Poultry and Dairy and Aquaculture scenarios. Based on data from Cederberg et al. (2009) and Bertilsson et al. (2014).

| | Dairy | Suckler |
|---|---|---|
| Milk yield, kg ECM per year | 11,000 | na |
| Losses of milk in stables, % | 3.5 | na |
| Recruitment rate, % | 22 | 10 |
| Calves per cow and year, % | 98 | 98 |
| First calving, month | 24 | 24 |
| Carcass weight of live weight, % | 53 | 53 |
| Human edible offal, % of live weight | 3 | 3 |
| Mortality rate off-springs, % | 1 | 1 |

### S4.2 Livestock production systems based on ecological leftovers

In the Ecological Leftovers scenario, pigs are reared on a diet consisting of 60% food waste, 30% cereals and 10% oil cake. The food waste was complemented with cereals and oil cake to ensure high growth rates and to compensate for variable nutrient composition in the waste (Westendorf, 2000). Hence the same feed conversion ratio and other production parameters as in the intensive pig production systems were used (Table S4).

Table S7 and S8 show data used for ruminant production in the Ecological Leftovers scenario. Feed rations are adjusted based on the availability of oil cake and fiber-rich by-products in the Projected and Healthy Diet variants.

**Table S7.** Feed, slaughter age and weight for ruminant production in the Ecological Leftovers scenario. Data for Projected Diet / data for Healthy Diets. Variation between Projected and Healthy diets due to varying amounts of by-products. Data from Cederberg et al. (2009), Bertilsson et al. (2014) and Spörndly (2003).

| **DAIRY PRODUCTION**<br>For the dairy cow feed consumption per year, for heifers and bulls consumption per lifetime. | | | |
|---|---|---|---|
| | Dairy cow | Heifer, dairy breed | Steer, dairy breed |
| Forage, kg d.m. | 4100 / 3400 | 4000 / 2200 | 4000 / 2200 |
| Oil cake, kg | 550 /550 | 220 / 600 | 220 / 600 |
| Fiberrich by-products, kg | 215 / 900 | 430 /1860 | 430 /1860 |
| Slaughter age, month | 90 | 24 | 24 |
| Slaughter weight, kg | 280 | 270 | 270 |
| **SUCKLER PRODUCTION** (only for Projected Diets)<br>For the suckler cow feed consumption per year, for heifers and steers consumption per lifetime. | | | |
| | Suckler cow | Heifer, beef cattle | Steer, beef cattle |
| Forage, kg d.m. | 3100 | 4000 | 4000 |
| Oil cake, kg | 0 | 220 | 220 |
| Fiberrich by-products, kg | 215 | 430 | 430 |
| Slaughter age, month | 147 | 24 | 24 |
| Slaughter weight, kg | 340 | 290 | 290 |

**Table S8.** Production parameters for cattle production in the Ecological Leftovers scenario. Based on data from Cederberg et al. (2009).

| | Dairy | Suckler |
|---|---|---|
| Milk yield, kg ECM per year | 5,000 + 1 * energy amount of concentrate/5 MJ | NA |
| Losses of milk in stables, % | 3.5 | NA |
| Recruitment rate, % | 19 | 10 |
| Calves per cow and year, % | 98 | 98 |
| First calving, month | 27 | 27 |
| Carcass weight of live weight, % | 53 | 53 |
| Human edible offal, % of live weight | 3 | 3 |
| Mortality rate off-springs, % | 1 | 1 |

## S5. Emission factors for enteric fermentation

In this study we used factors for the yearly methane production per animal for different animal types calculated using the method by Lindgren (1980) and reduced by 20% to account for the technical mitigation potential (see section 2.1 in main paper). The factors were published in a report by Berglund et al. (2009) and are summarized in Table S9 below.

**Table S9.** Emissions factors methane emissions from animals (Berglund et al 2009)

| | Emissions of methane, kg $CH_4$ per animal and year |
|---|---|
| Dairy cow milk yield 11,000 kg EMC/year | 109 |
| Dairy cow milk yield 6,000 kg EMC/year | 98 |
| Suckler cow | 62 |
| Bulls, heifers, steers | 44 |
| Pig | 1.2 |

## S6. Available resources and their use in the Ecological Leftover scenario

The amount of livestock products that can be supplied in the Ecological Leftovers scenario depends on the availability of feed from pastures and by-products from the production of the plant-based food. The amount of pasture in the region was retrieved from FAOSTAT (FAO, 2015a). Out of the total amount of pasture, 62 Mha, using the same methodology as in Smith et al. (2008) it was determined that 52% of this is located in moist cool climate zones with an average above ground net primary production of 5.7 tons of d.m. per hectare and 48% in moist warm climate zones with an production of 8.2 tons of d.m. per hectare (IPCC, 2003). The pasture utilization rate was set to 65%. In cold climate regions it was assumed that grazing was restricted to the summer months (half of the year) and in order to keep grazing livestock on these pastures it was necessary to produce winter feed (forage) on cropland in equivalent amounts to the biomass grazed.

The Ecological Leftovers scenario was the only scenario that used food waste as animal feed, as this practice is aligned with the principle of limiting livestock production to using non-edible food resources as feed. Currently, feeding food waste to livestock is prohibited within the (EU, 2011) due to the risk of contamination and infection. However, with proper sanitization and handling, food waste is a valuable feed ingredient to especially pigs (Westendorf, 2000). The food waste was complemented with some cereals using cropland for its production and oil cake to ensure high growth rates. As in all other scenarios by-products from the production of plant-based foods for human consumption were used as feed (section S4).

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